Development of a Hydrologic Climate-Response Network for Resource Assessments

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USGS Maine Water Science Center

Purpose

- Demonstrate usefulness of existing hydrologic networks for monitoring and assessing climate change
- It can be difficult to directly assess the impact of climate change on resources
- Instead use a two step process
  - Effect of climate change on hydrologic processes
  - Effect of changes in hydrologic processes on resources

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Climate Research in the USGS Maine Water Science Center

- Since 2001 the USGS MeWSC has evaluated the impact of climate change on long-term hydrologic records in New England
- Primary work demonstrated strong relationships between climate and some hydrologic variables
- Hydrologic variables displayed consistent temporal and geographic trends

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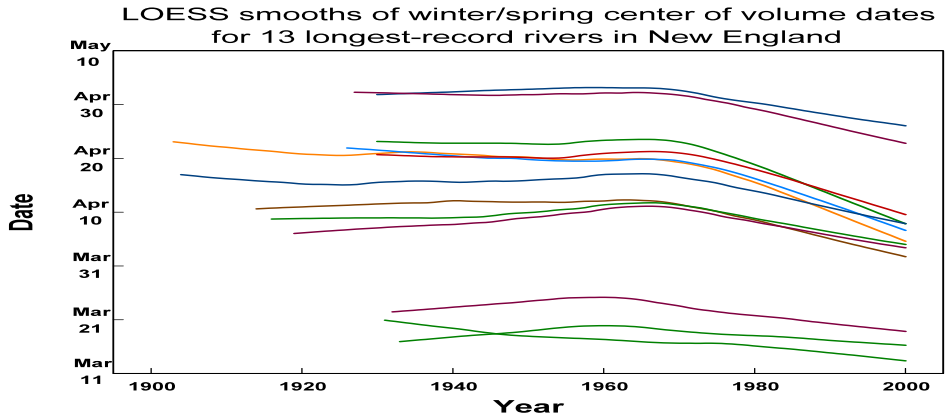
Why Study Climate Change in Maine?

Hydrology is Sensitive to Climate

- Spring runoff dominates the annual hydrograph
- Occurring significantly earlier in northern New England in recent years
- Timing related to air temperatures



Hodgkins and others, 2003

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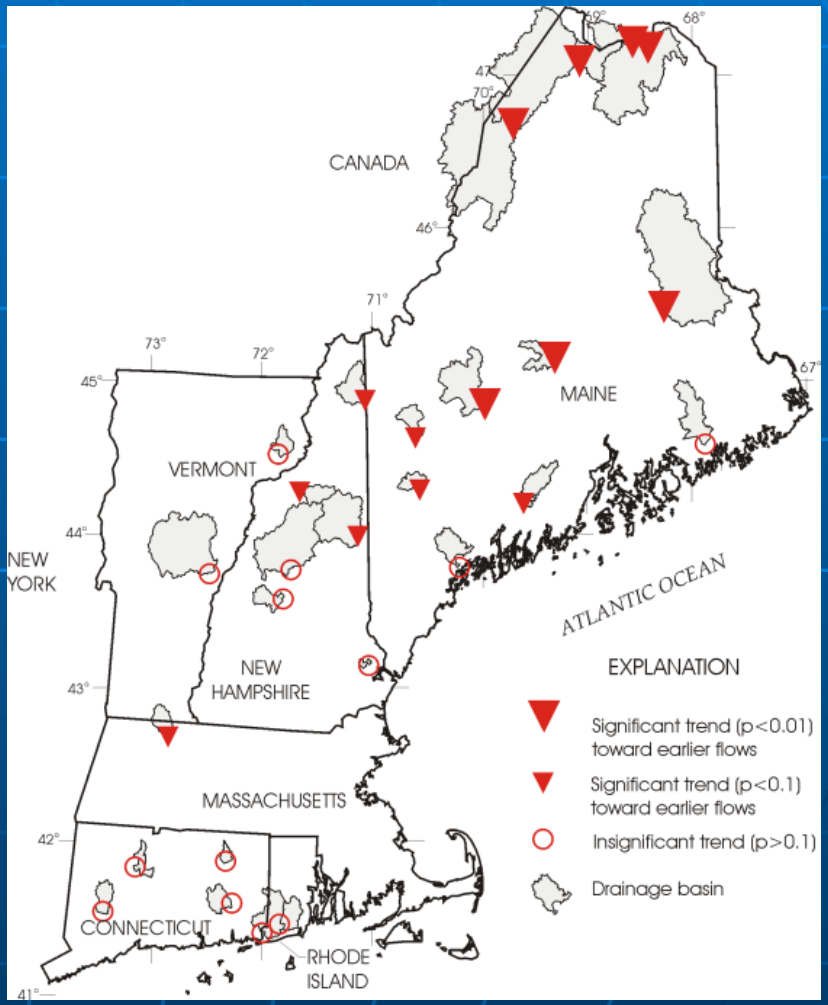
Why Study Climate Change in Maine?

Abundant Hydroclimatic Data

- Abundance of historic hydrologic stations
  - Long-term records
  - Not impacted by flow regulation
  - Little urbanization
- Large climate gradient
  - Mountains to the Atlantic Coast
  - Part of a larger regional gradient



Hodgkins and others, 2003

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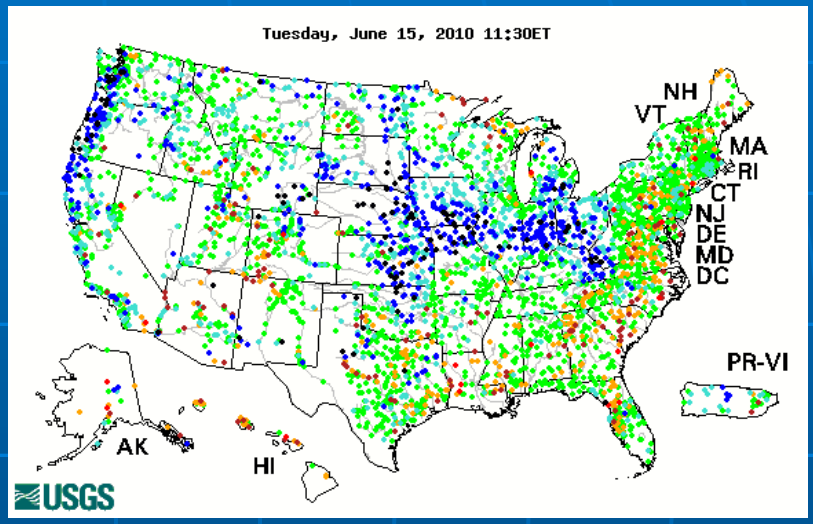
Traditional Hydrologic Networks

- Not designed for monitoring climate change
- Stations were located for flood control, regulation, water use, and local uses
- Traditional variables were not necessarily sensitive to climate change
- Reporting based on the assumption of stationarity



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Climate Response Program

Goals

- Define impact of climate variation on hydrologic processes
- Provide an early warning of hydrologic response to climate change
- Provide systematic information to resource managers

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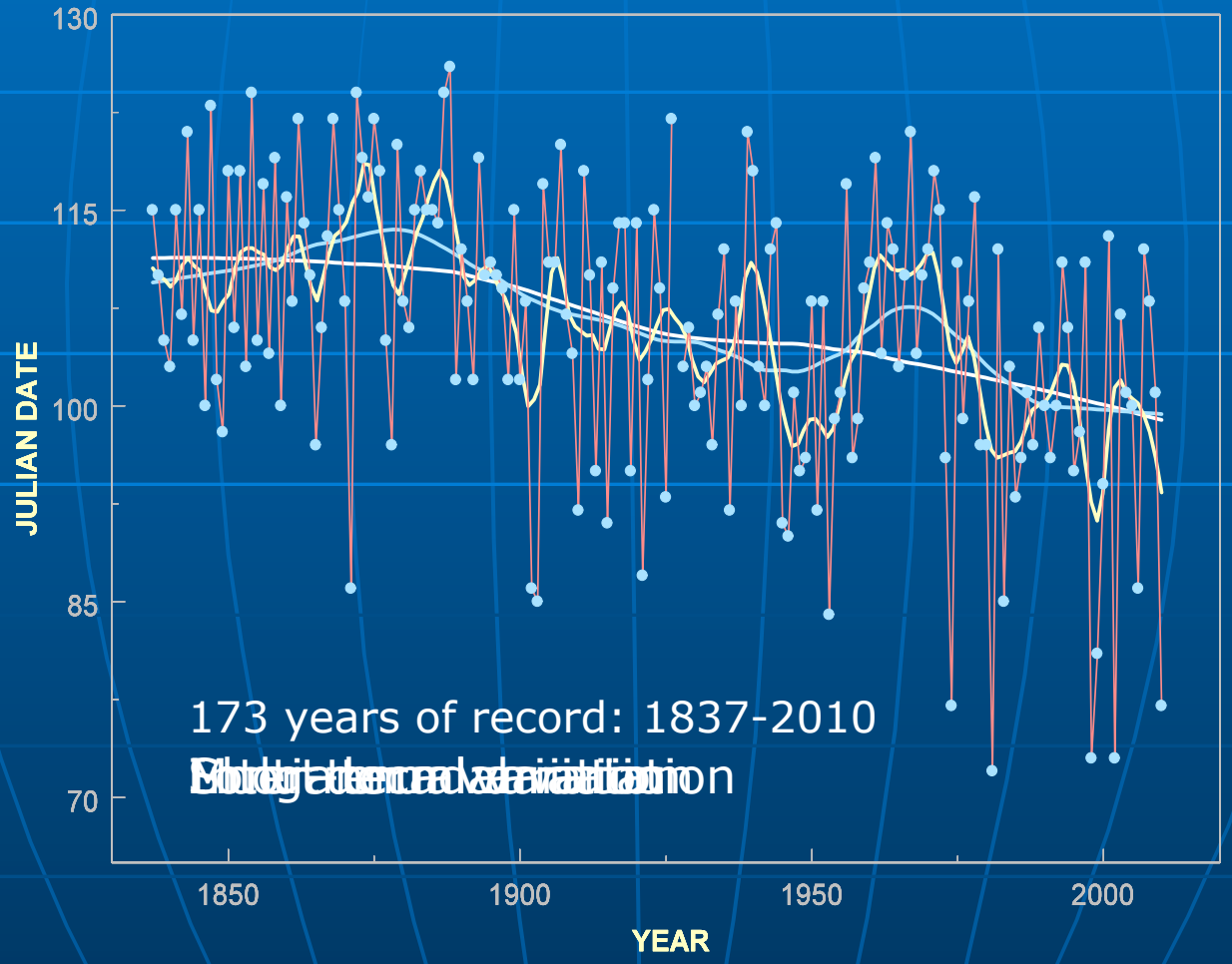
Impact of Climate on Hydrologic Processes

Temporal Variation

Damariscotta Lake ice-out dates



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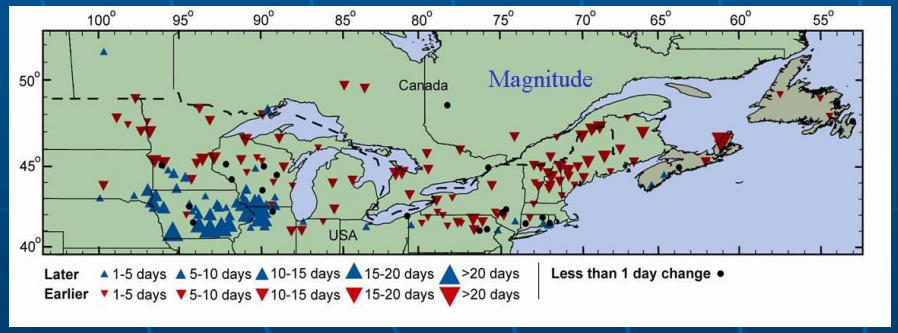
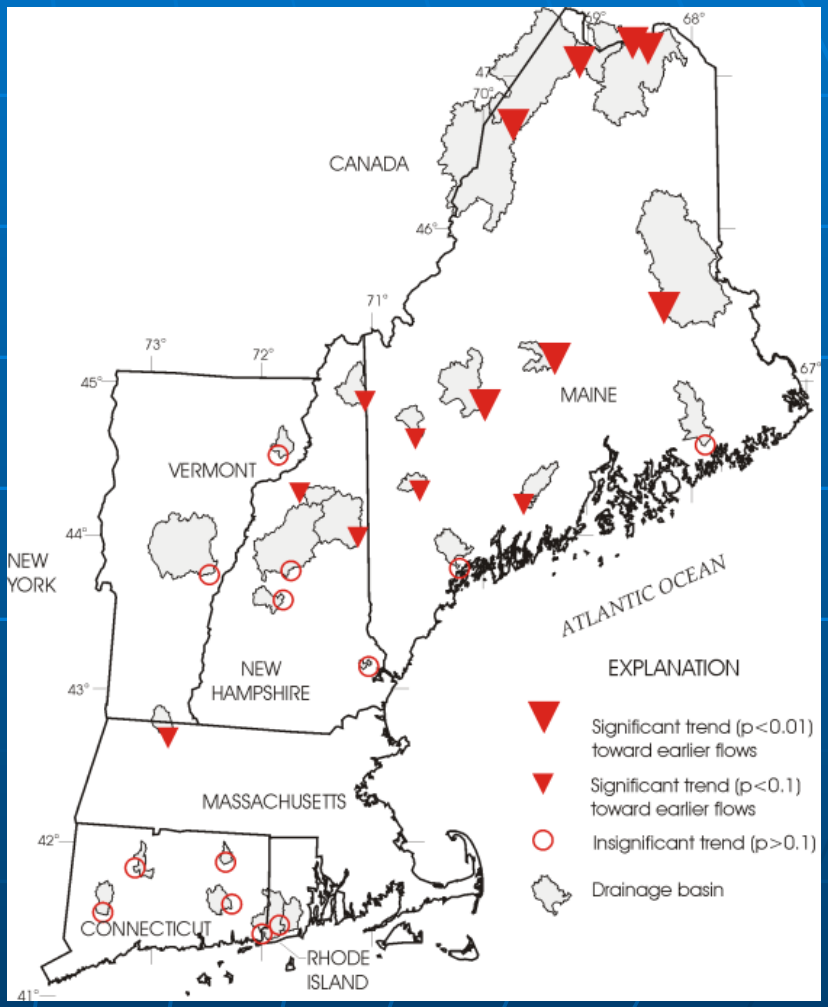
Impact of Climate on Hydrologic Processes

Regional Variation

- Maine
  - Timing
  - Mountains to the Coast
- New England
  - Significance
  - North to south
- Regional gradients
  - Direction



Hodgkins and Dudley, 2006



Hodgkins and others, 2003

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Impact of Climate on Hydrologic Processes

Regional Variation

- Different areas of New England may have different key variables —even adjacent areas
- Different variables may be appropriate for different scales

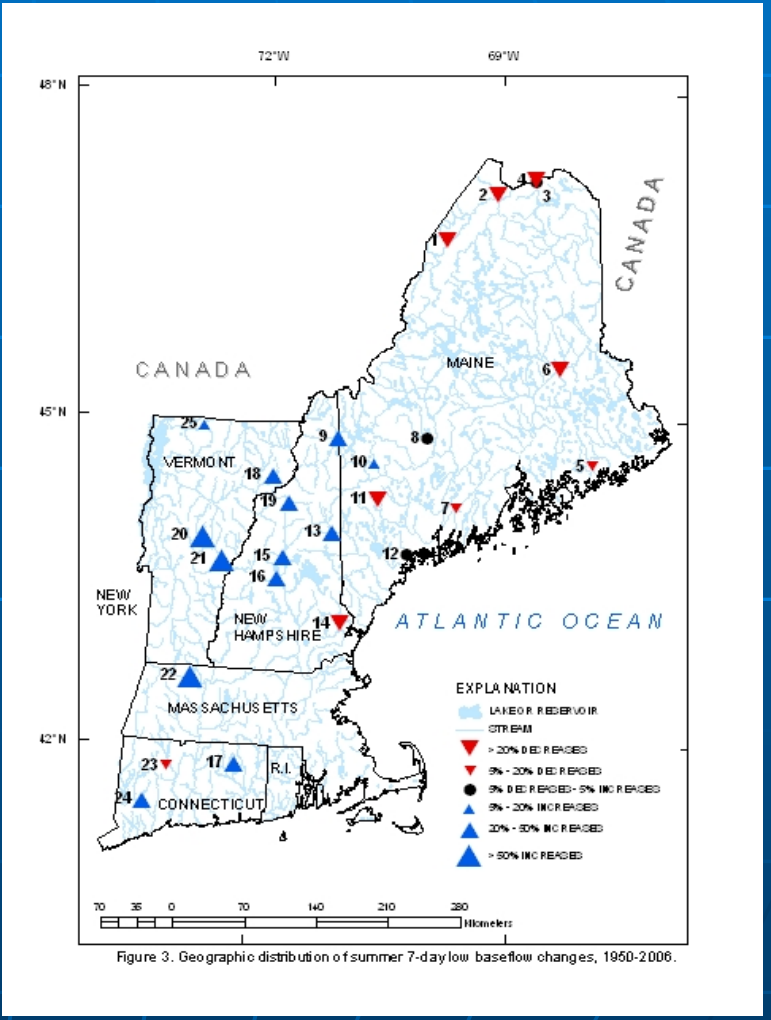

Figure 3. Geographic distribution of summer 7-day low baseflow changes, 1950-2006.

Hodgkins and Dudley, 2010

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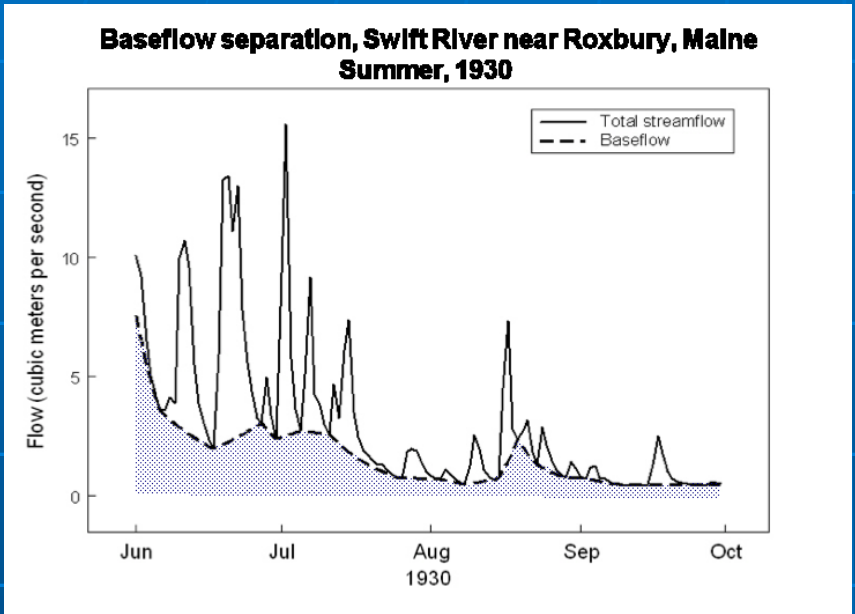
Types of Hydrologic change

Variations in Quantity



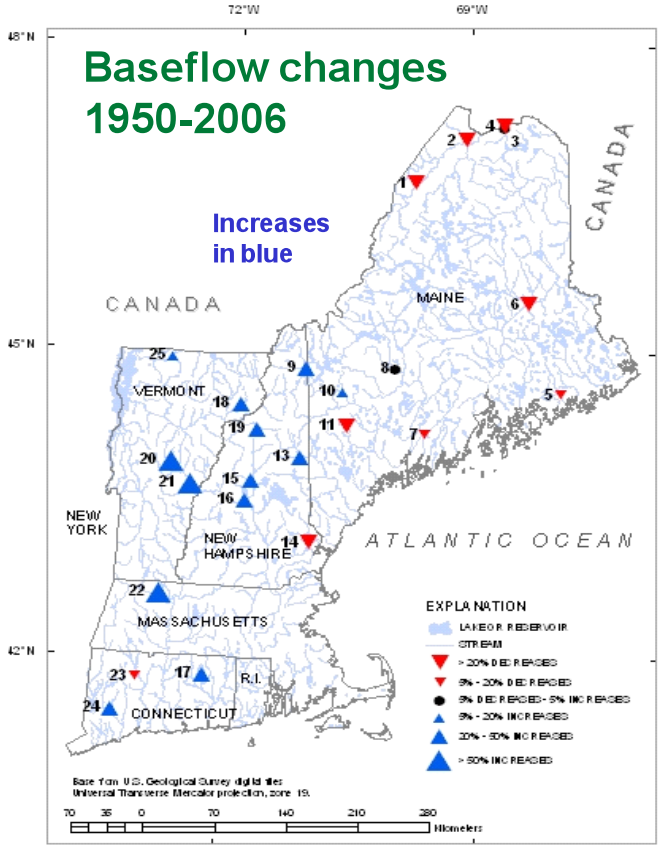


Figure 3. Geographic distribution of summer 7-day low baseflow trends, 1950-2006.

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Types of Hydrologic change

Other Variations

- Frequency of events
  - Number of rain events
  - Occurrence of extreme events
- Changes to the hydrologic system
  - Changes in snow versus rain
  - Changes in river ice formation

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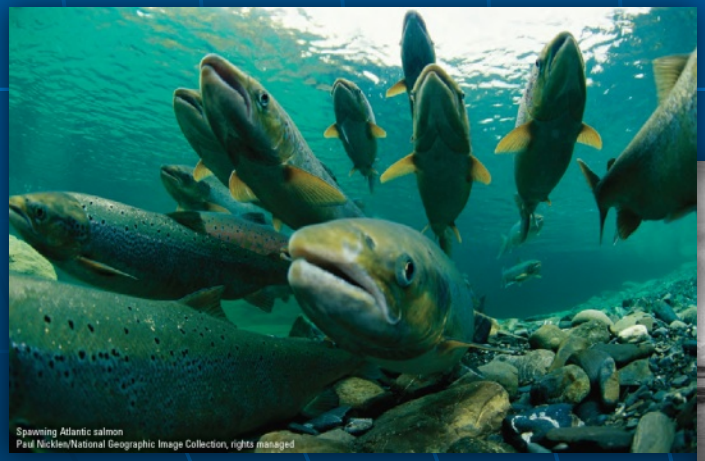
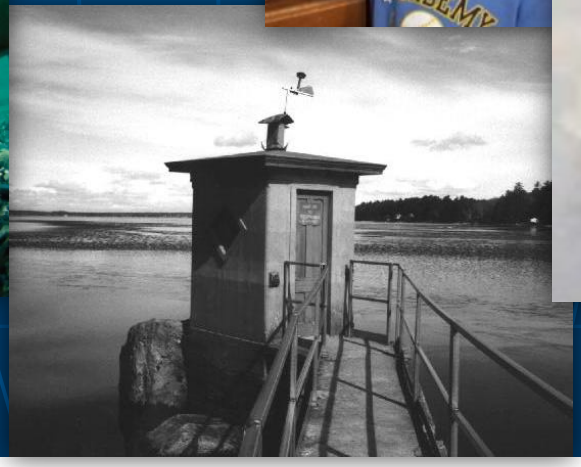
Implement Early Warning Monitoring Network

Choosing Key Hydrologic Variables

- Response to climate change
- Important to resource managers
  - Ecosystem function
  - Water availability and use
  - Hazards
  - Energy





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Key Hydrologic Variables

- **Streamflow**
  - Timing of winter-spring runoff
  - Magnitude of annual peak flow
  - Magnitude of summer baseflows
- **Groundwater**
  - Amount of seasonal recharge
  - Timing of seasonal peaks
- **River ice**
  - Days of ice-affected flow
  - Ice thickness
- **Lake ice**
  - Date of spring ice-out
- **Late-winter snowpack**
  - Depth
  - Density
  - Water equivalent

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Implement Early Warning Monitoring Network

Define Hydrologic Response Regions

- Spatial variability of hydrologic variables
- Regional boundaries
  - Major watersheds
  - USEPA Ecoregions
  - Biophysical regions
- Important resources
  - Critical habitat
  - Native American lands
  - Federal lands
  - Drinking-water supplies

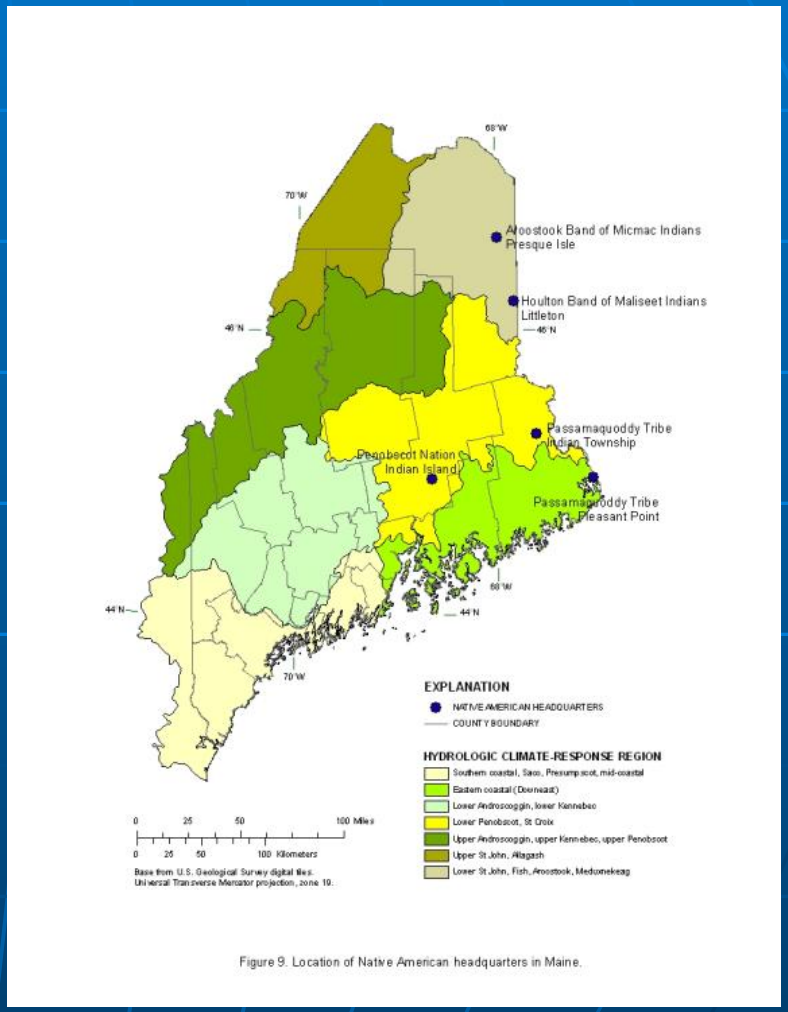

Figure 9. Location of Native American headquarters in Maine.

Native American headquarters

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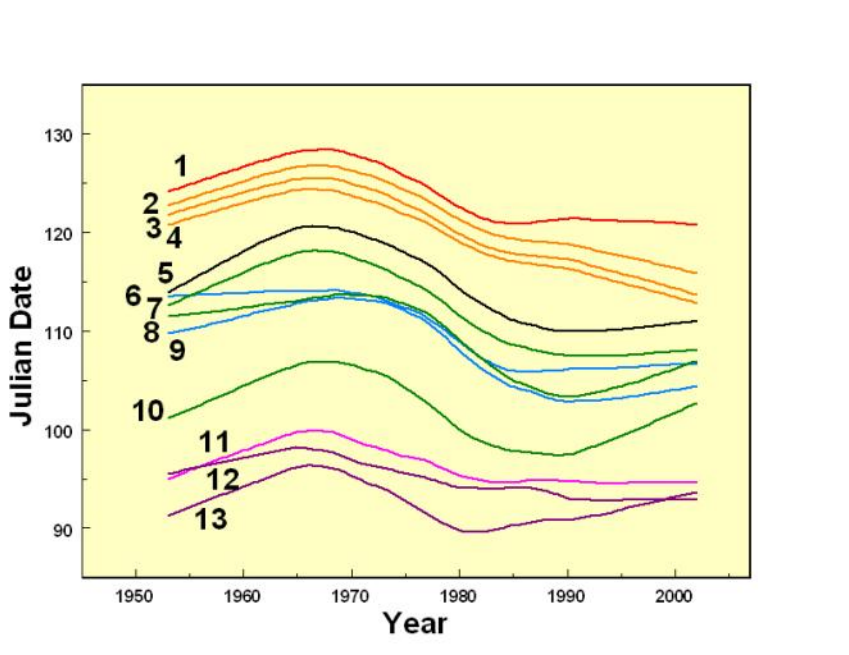
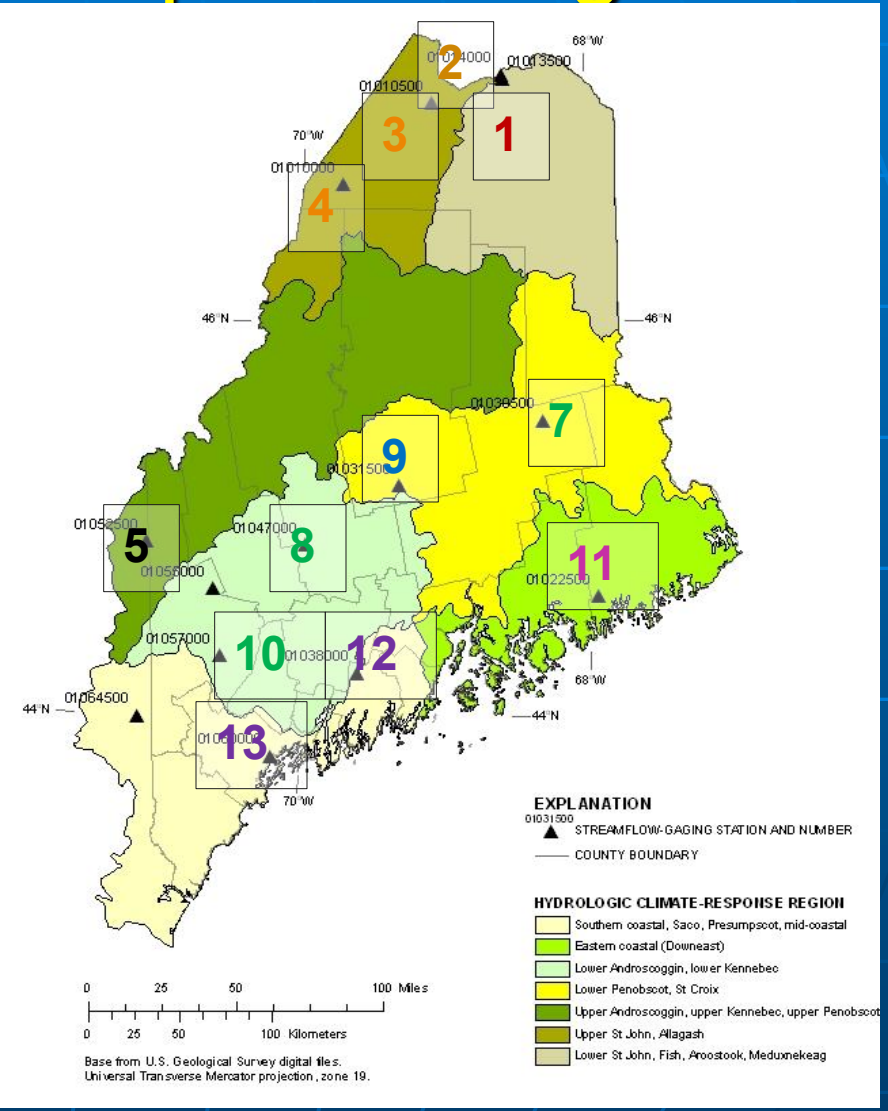
Define Hydrologic Response Regions

- Historical changes in timing of winter/spring runoff, 1953-2002





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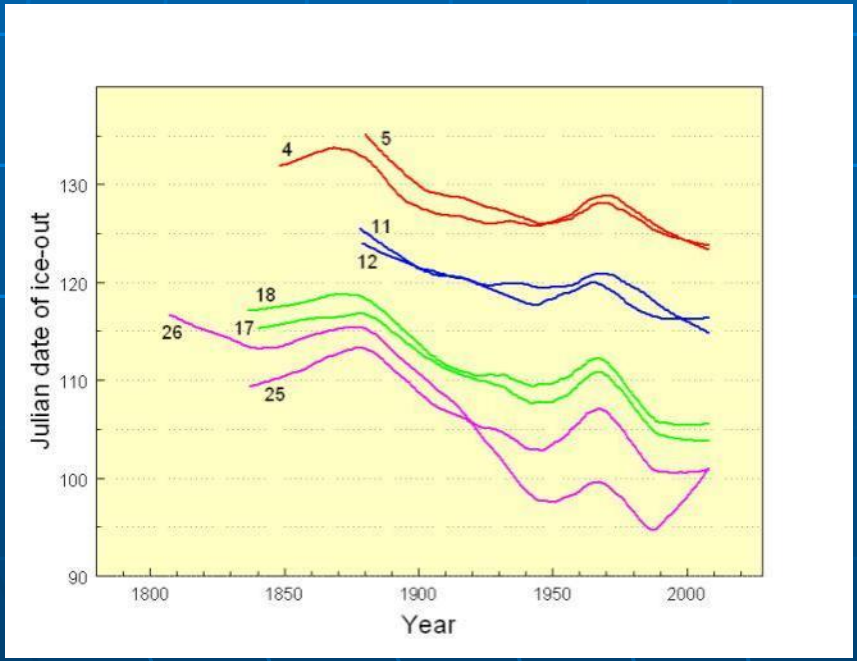
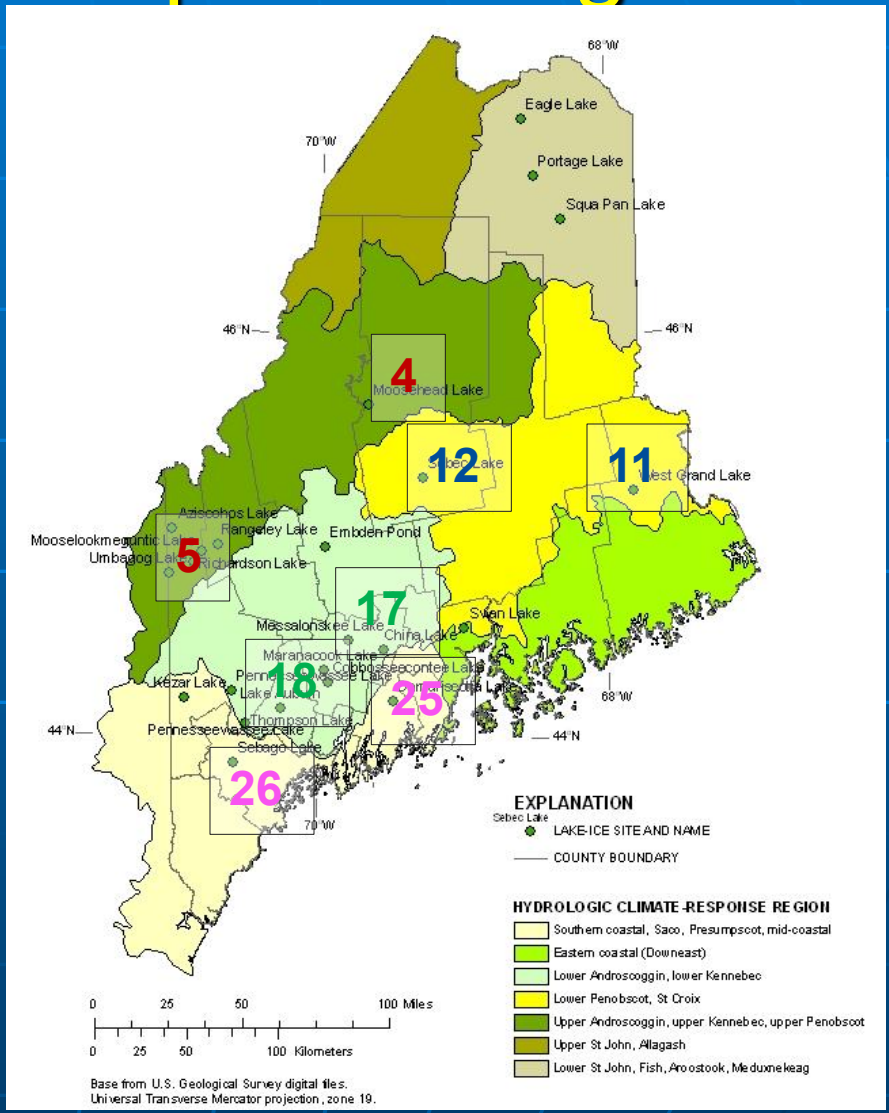
Implement Early Warning Monitoring Network

Define Hydrologic Response Regions

- Historical changes in timing of lake ice-out dates, 1834-2008





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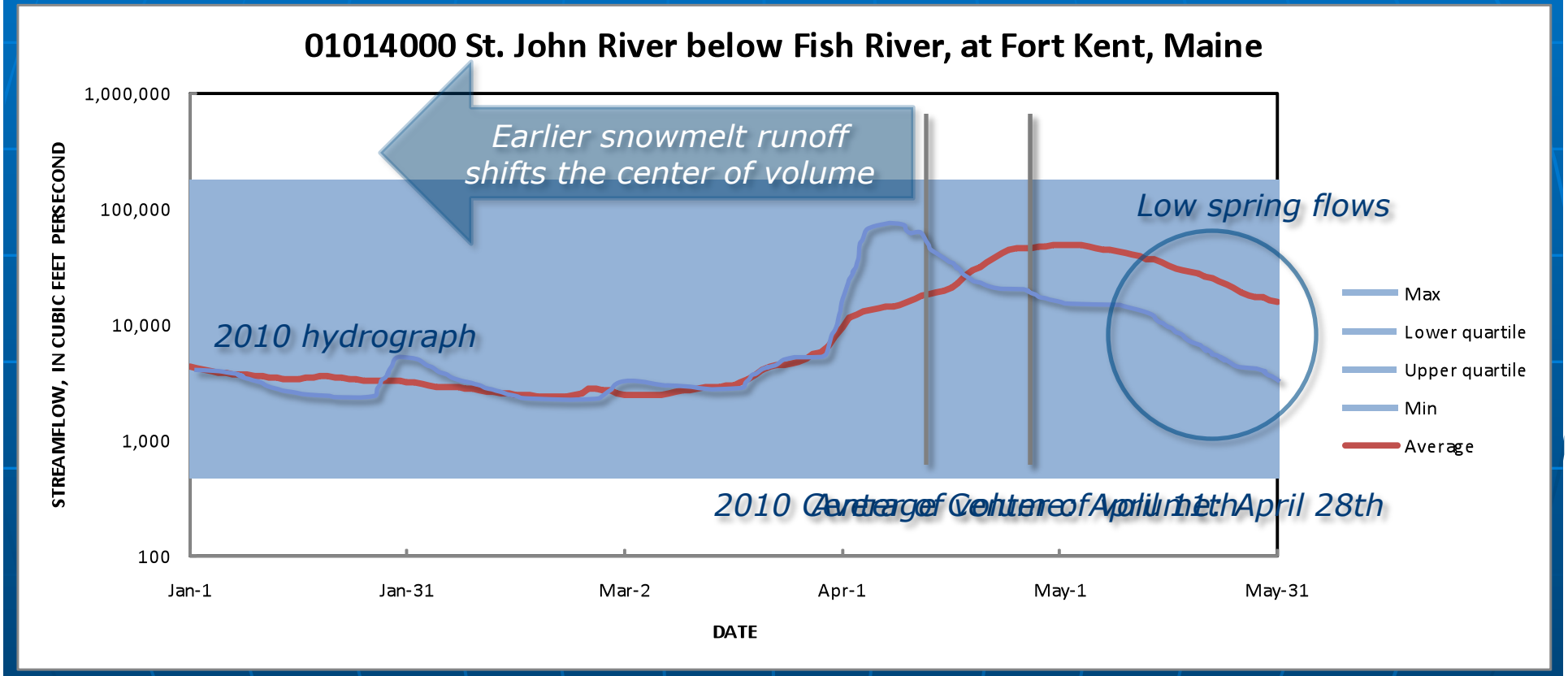
Operate Early Warning Monitoring Network

Update Variables



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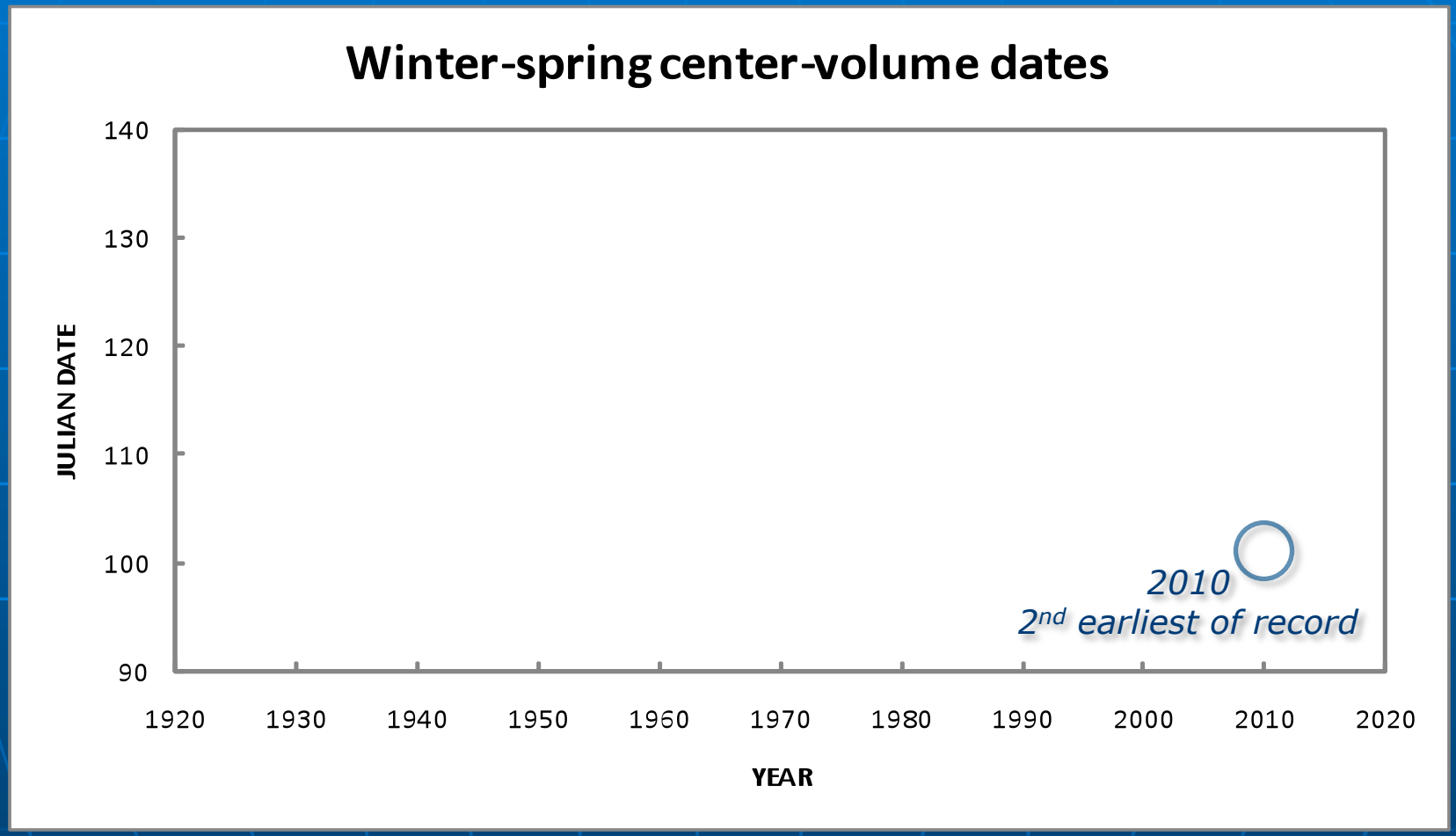
01014000 St. John River below Fish R., at Fort Kent, Maine



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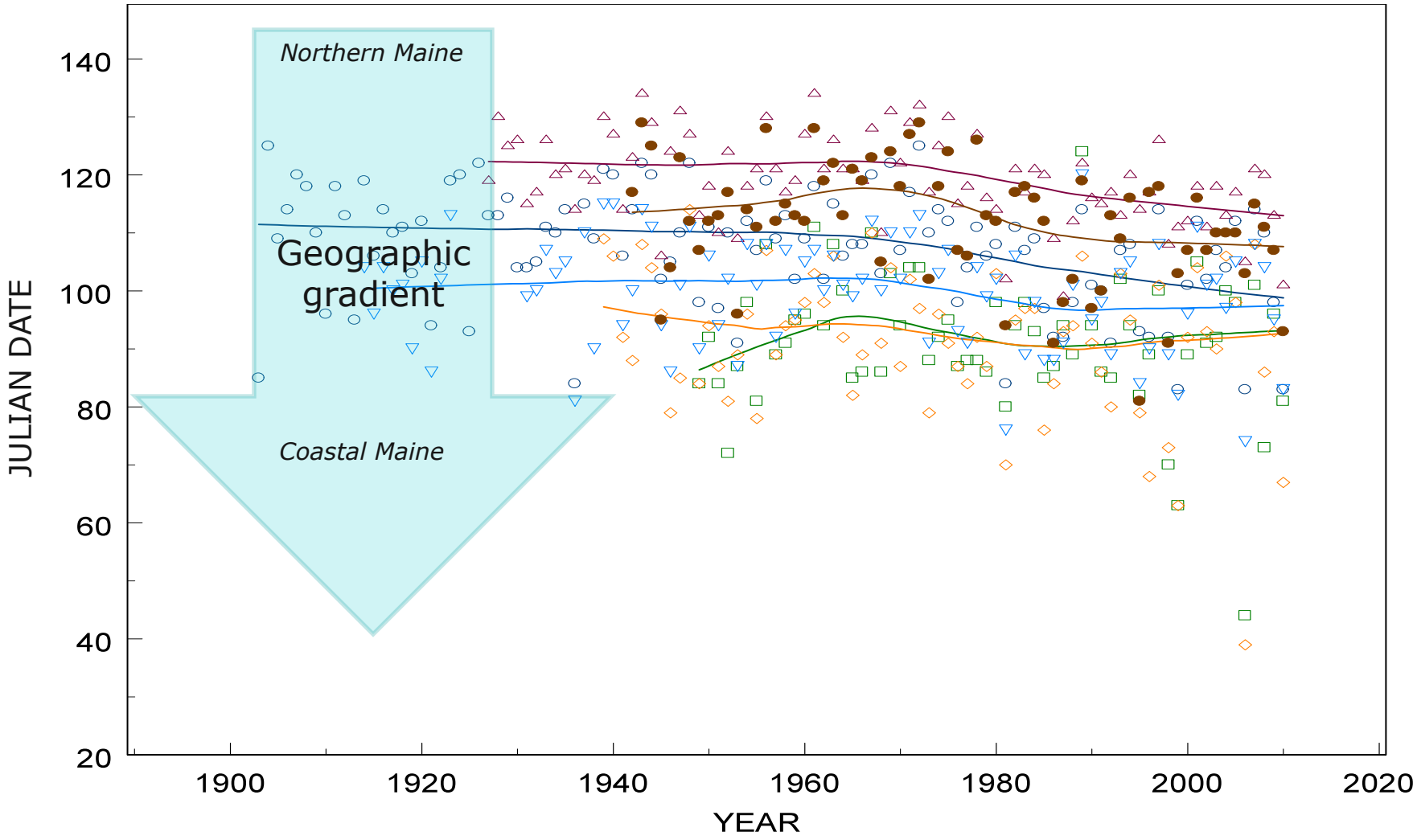
Winter-spring center volume dates through 2010 for each of six Maine climate response



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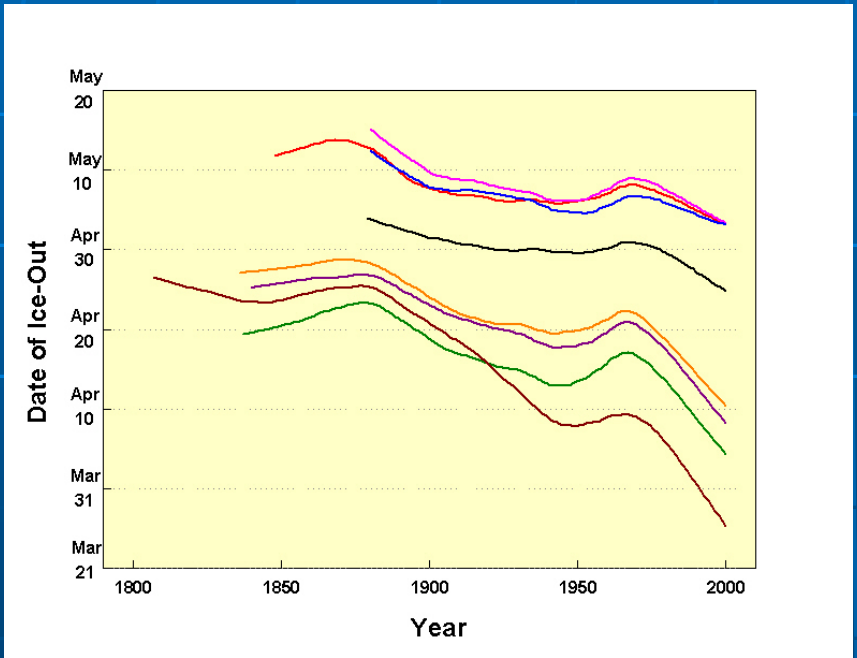
Operate Early Warning Monitoring Network

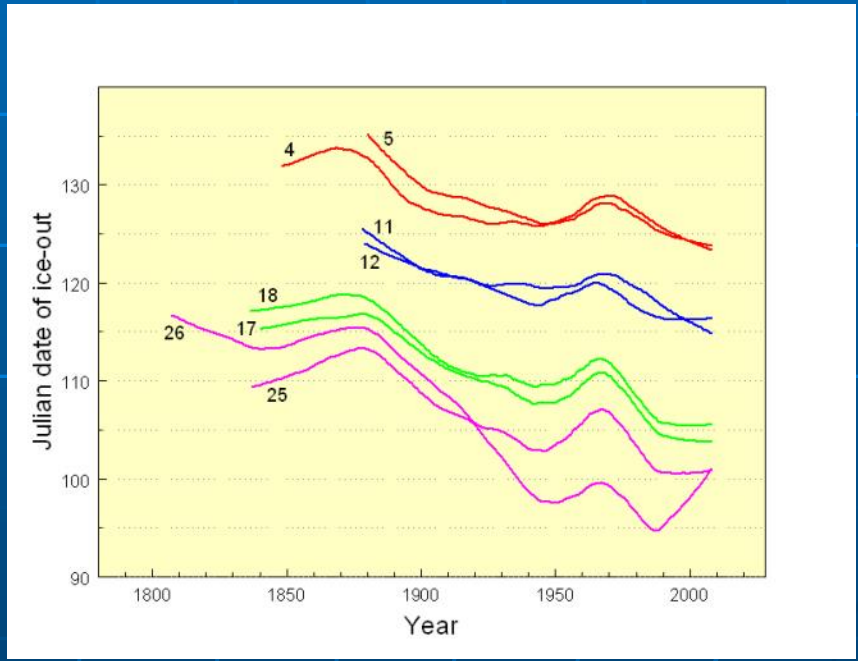
Update Trends

Lake Ice Out Dates

Completed in 2000



Completed in 2009



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Early Warning Monitoring Network

Ongoing Activities

- Gap analysis
  - Identify missing data collection sites
- Identify shorter-term monitoring sites
  - Shorter records (20 to 50 years)
  - Minimal impact
- Evaluate new indicators
- Archiving
  - Develop strategy for maintaining record between trend analysis
  - Construct data base

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Early Warning Monitoring Network

Future Activities

- Additional information analyses
  - Long-term inter-annual variability
  - Weather versus climate
  - Attribution (natural versus anthropogenic CC)
- Regional applications
  - Evaluate variables at different scales
  - Expand to New England or the Northeast
  - Incorporation information into USGS National Climate Effects Network

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Provide information to resource managers

- Identify watersheds in each region
  - Representative
  - Important to resource managers
- Watershed models
  - Calibrated for key HCRN variables
- Additional data collection
  - Continuous water temperature

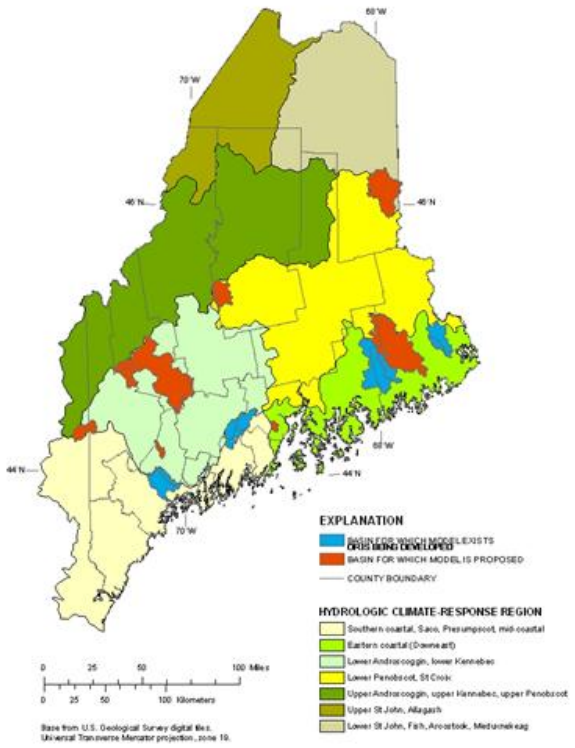

Figure 12. Location of drainage basins with rainfall-runoff models in Maine.

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Climate Response Network and Watershed Models

- Hydrologic Climate Response Network provides:
  - Key hydrologic variables sensitive to climate changes
  - Temporal and geographic context
  - Appropriate variable for different scales
- Calibrated watershed models provide:
  - Means to link climate and hydrology to ecological models
  - Ability to make projections about future conditions
  - Temporally and spatially explicit water budgets

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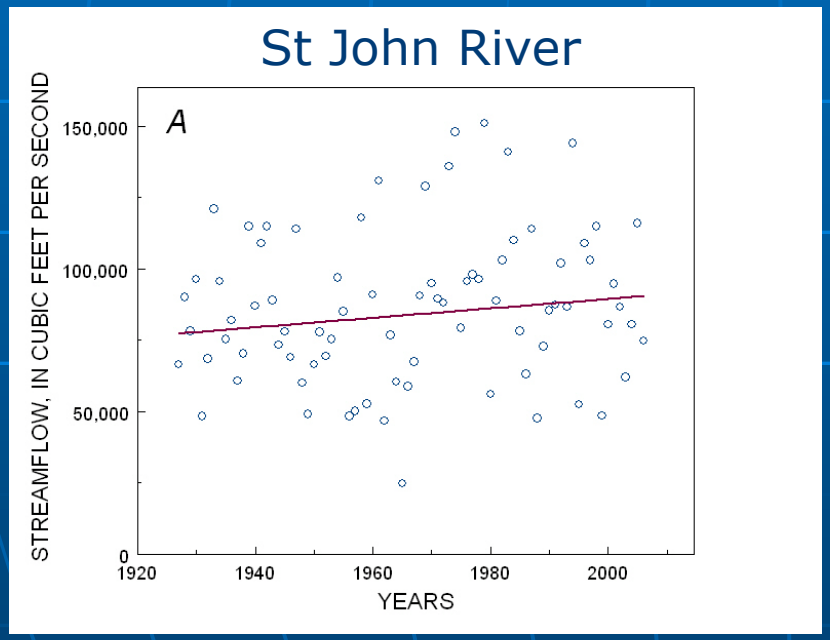
Effect of Climate Change and Variability on Design Flood Flows in Maine

- **HCRN key variable:**
  Annual peak flow



- **Resources impacted:**
  Bridges and culverts
- **Resource agencies:**
  Maine DOT

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Effect of Future Climate Change and Variability on Design Flood Flows in Maine

- HCRN key variable:
  Annual peak flow

- Resources impacted:
  Bridges and culverts
- Resource agencies:
  Maine DOT, Acadia National Park

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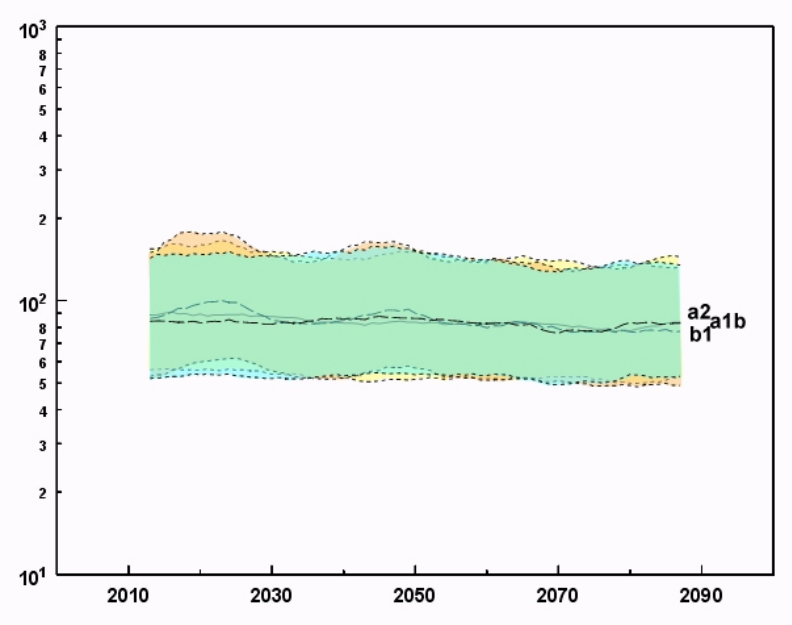
Effects of Climate Change on Low Flows and Water Temperatures

- HCRN key variable:
  Summer baseflows



- Resources impacted:
  A. Salmon survival during summer low flow conditions
- Resource Agencies:
  NOAA-NMFS/USFWS/MDMR

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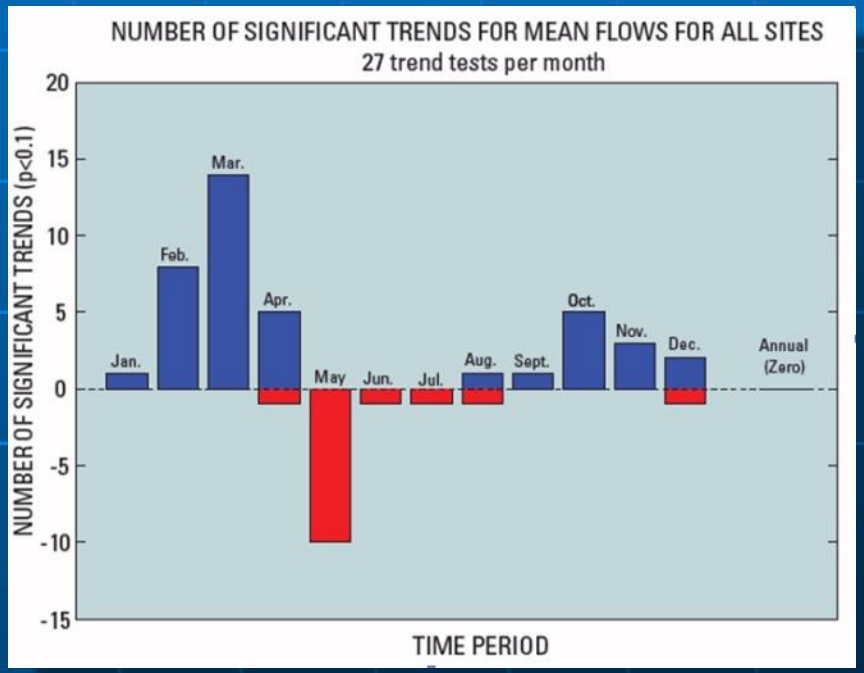
Timing of Snowmelt Runoff in Downeast Rivers

- **HCRN key variable:**
  Winter/spring runoff



- **Resources impacted:**
  Timing and success of Atlantic salmon smolt migration
- **Resource Agencies:**
  NOAA-NMFS/USFWS/MDMR

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Snowpack and Forest Carnivores

- HCRN key variable: Snowpack density and depth

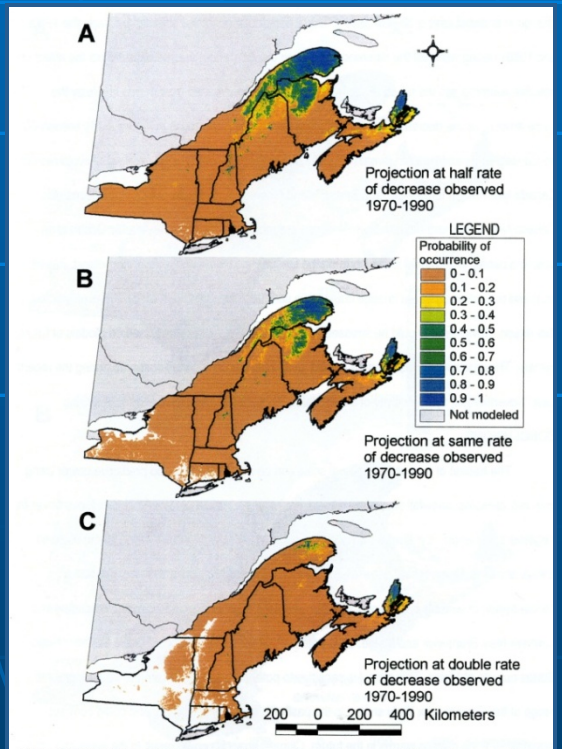

Figure 2.14. Projection of Canada lynx habitat assuming (A) future snowfall levels decrease at ½ the rate of change between the 1970s and 1980s, (B) future snowfall levels decrease at a rate equal to the rate of change between the 1970s and 1980s, and (C) future snowfall levels decrease at twice the rate of change between the 1970s and 1980s.

- Resources impacted: Canada lynx and snowshoe hare
- Resource agency: U.S. Fish and Wildlife

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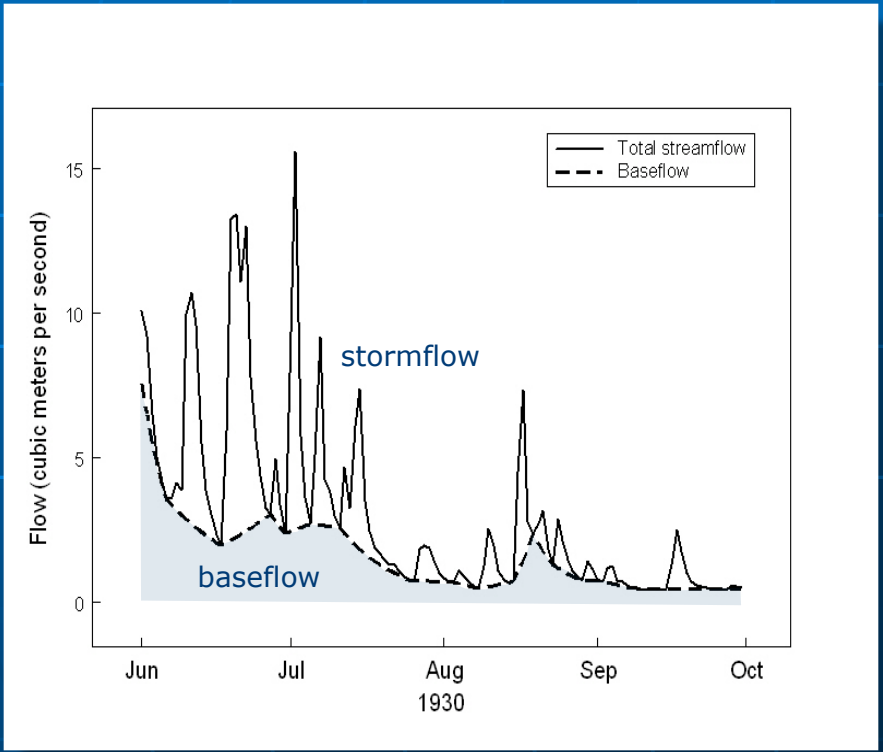
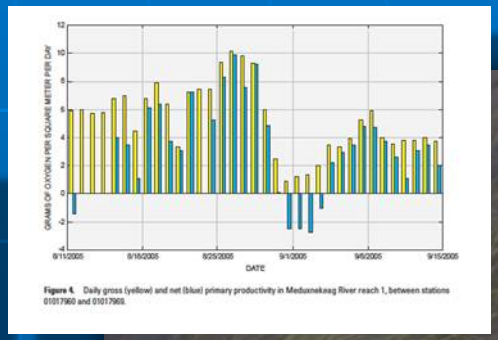
Community Metabolism in Freshwater Streams

- **HCRN key variable:** Summer baseflows





- **Resources impacted:** Primary productivity and community respiration in the Meduxnekeag River
- **Resource agencies:** Houlton Band of Maliseet Indians, BIA

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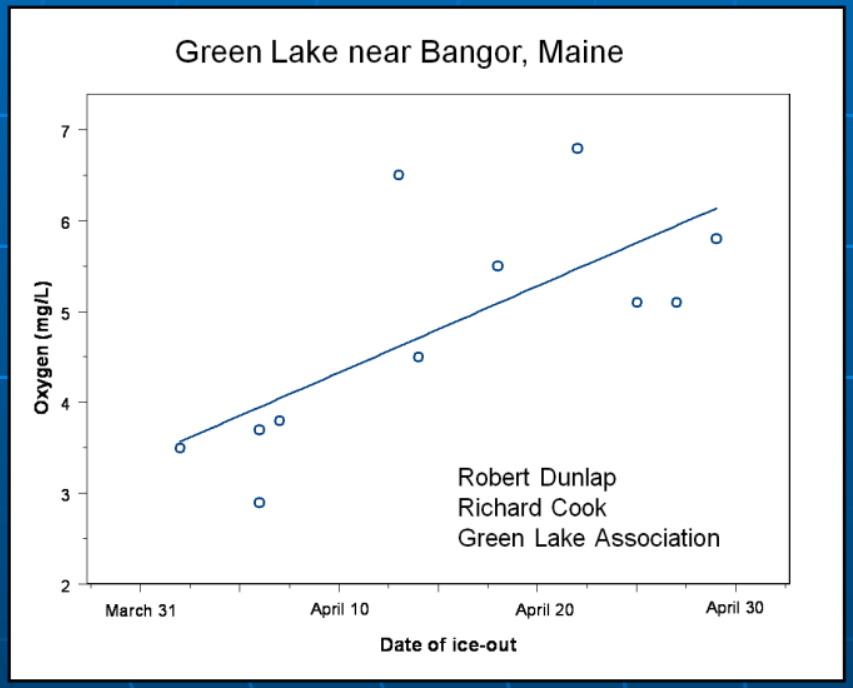
Effects of Climate Change and Eutrophication on Hypolimnetic Oxygen Demand in Lakes

- **HCRN key variable:**
  Lake ice-out date



- **Resource impacted:**
  Hypolimnetic Biota

- **Resource agency:**
  Acadia National Park

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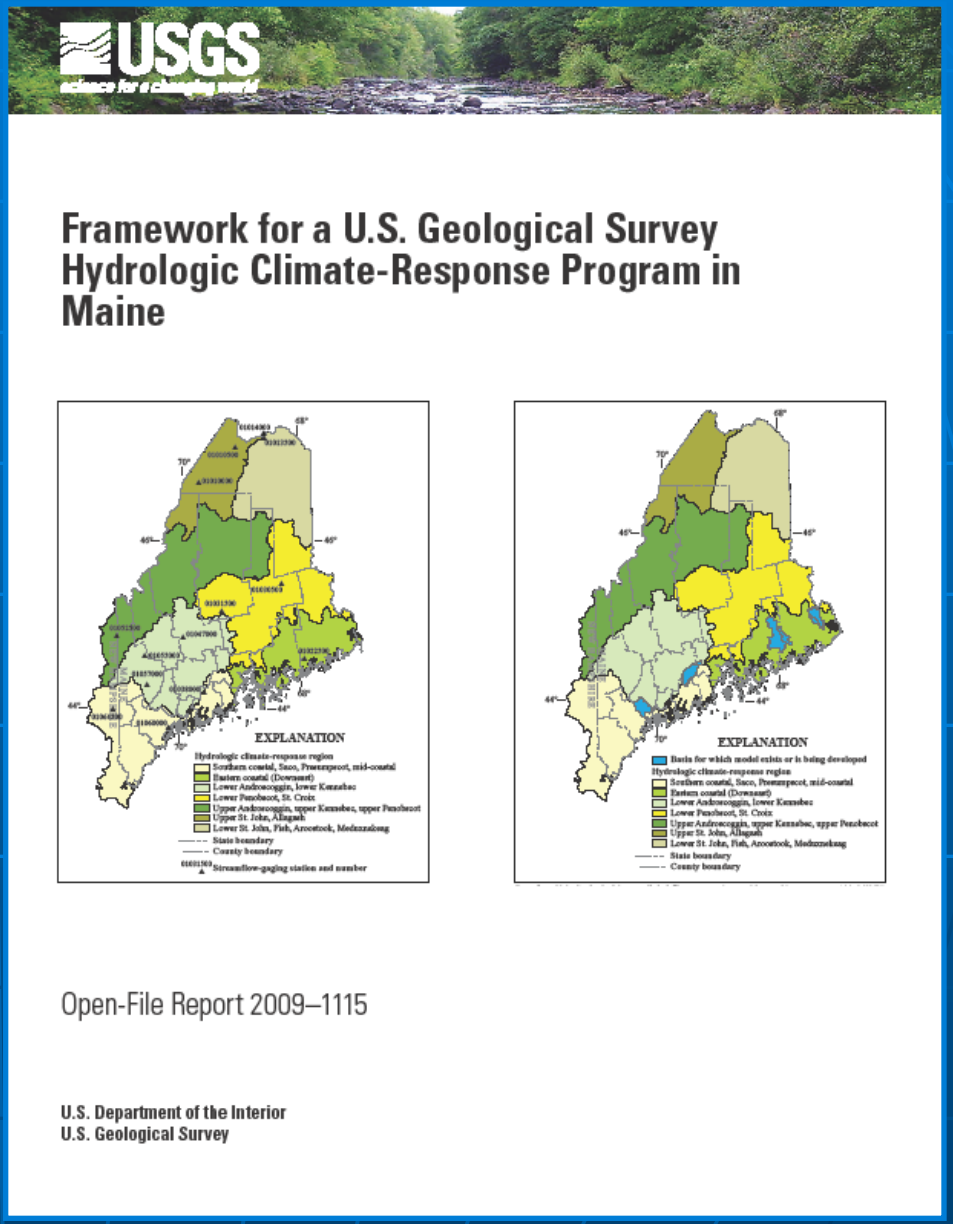
- Contact information
  rmlent@usgs.gov
  207-622-8201 ext. 102
- Full report:
  http://pubs.usgs.gov/of/2009/1115/
- Fact Sheet:
  http://pubs.usgs.gov/fs/2009/3044/
- All reports and info:
  http://me.water.usgs.gov/



Hodgkins, Lent, Dudley, and Schalk, 2009

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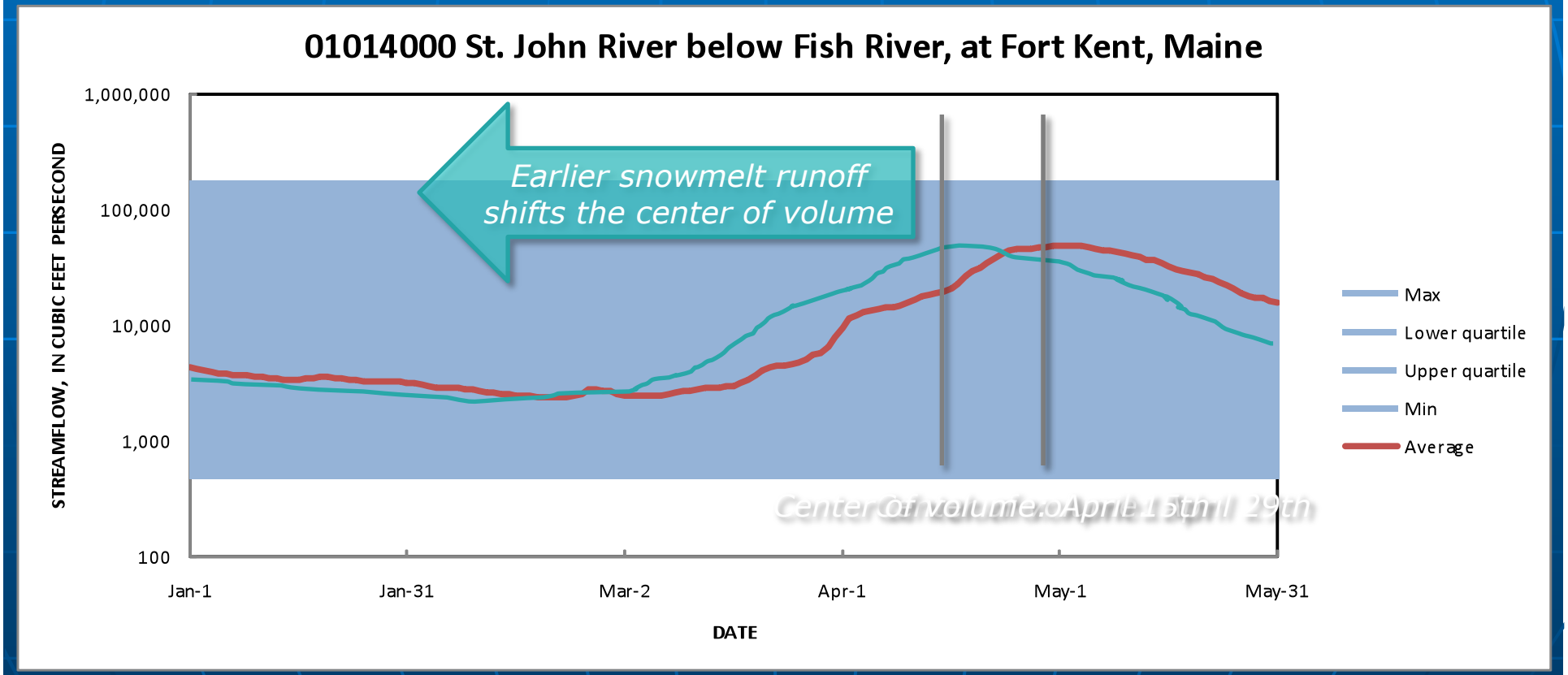

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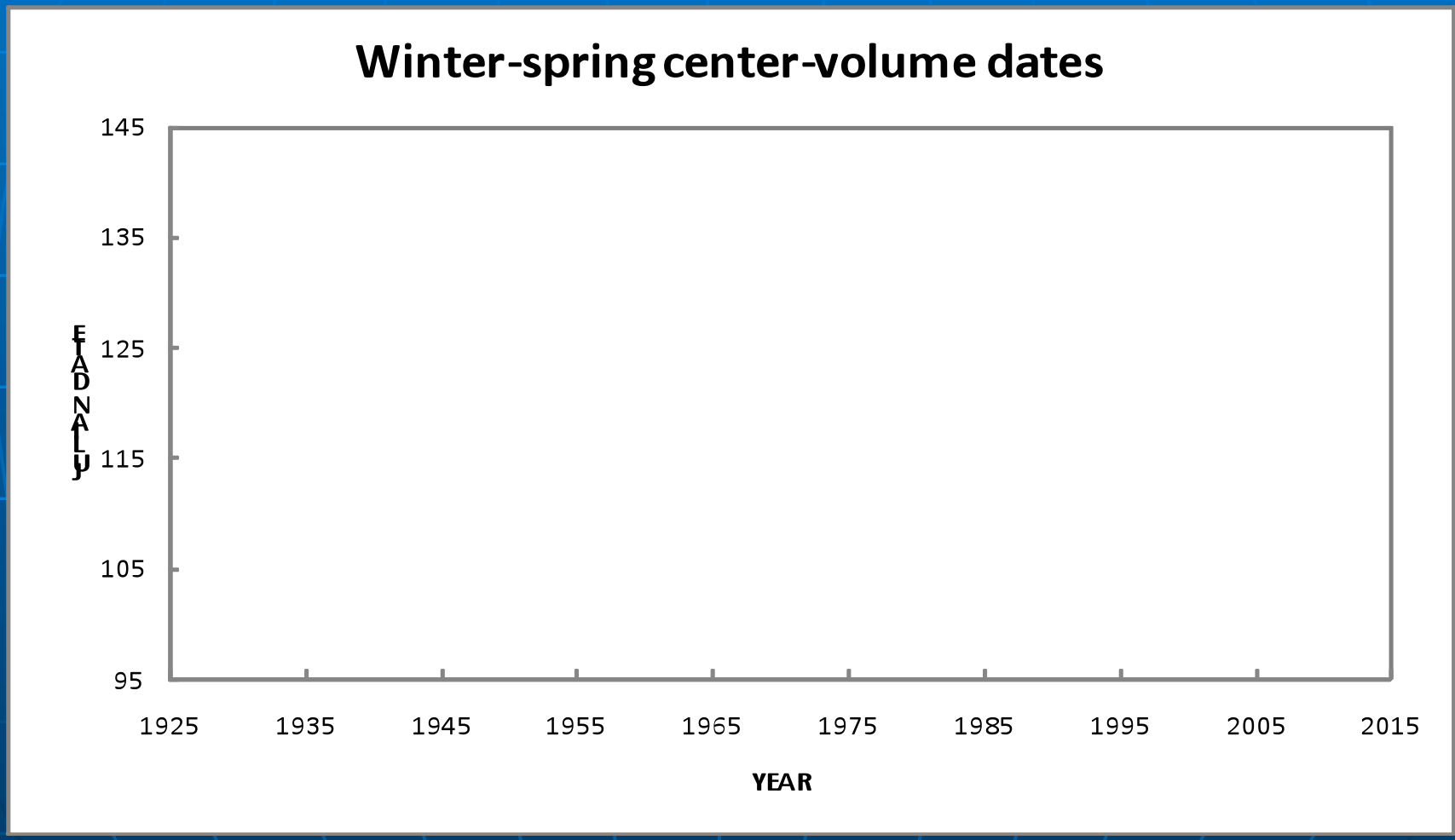

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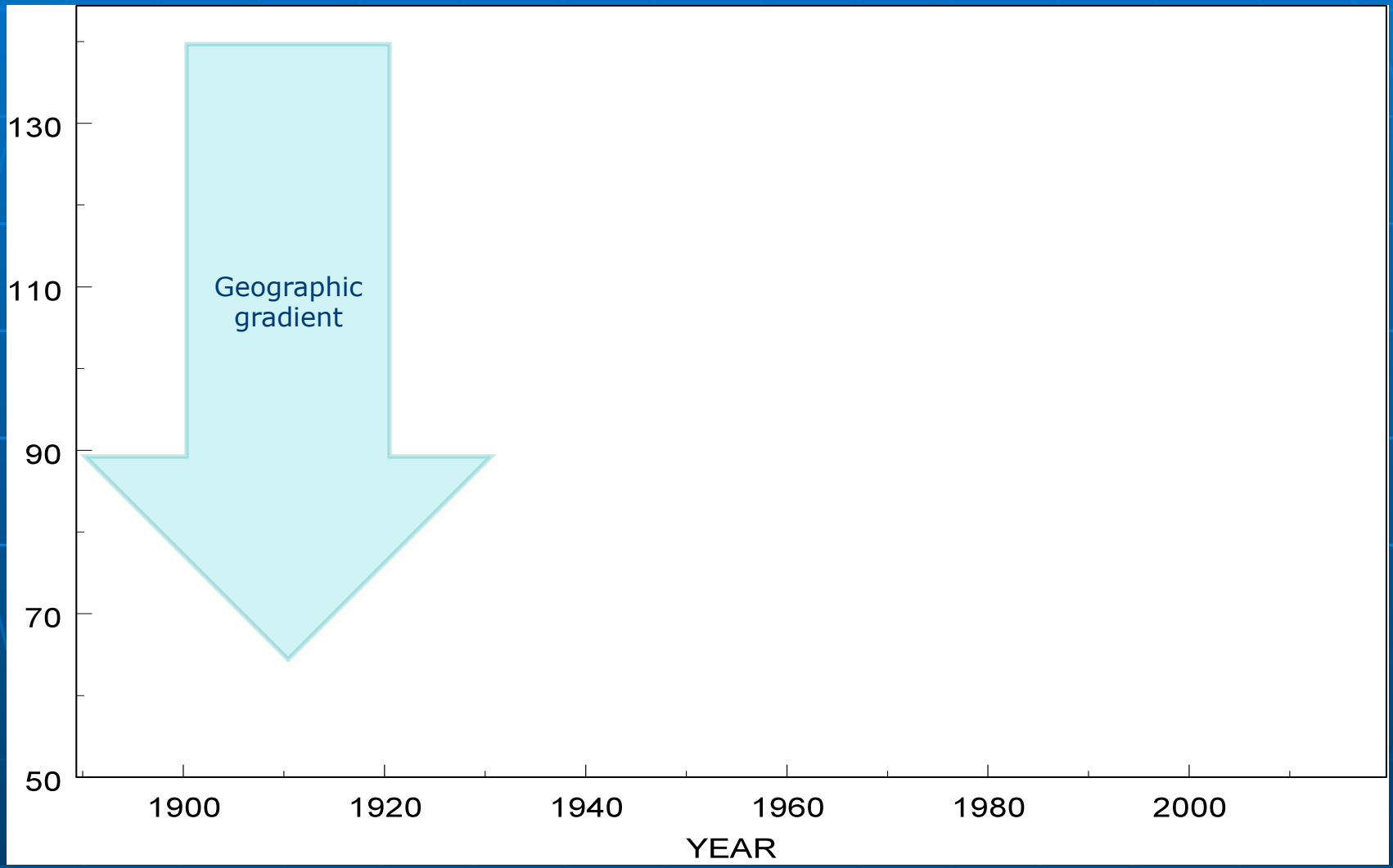
Winter-spring center volume dates for each climate response unit



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